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ENVIRONMENTAL, SOCIAL AND ECONOMIC BENEFITS OF TREE PLANTATIONS FOR URBAN SOCIETIES

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ABSTRACT

Numerous studies have been conducted on urban trees, analysing such topics as composition, thickness, height and health status for purposes of tree management. Through a review of the literature, we not only focus on the aesthetic aspects of urban trees, but also analyse their environmental, social and economic benefits. The review is divided into three sections. First, studies on the environmental benefits of urban trees were reviewed, including the biotic and abiotic factors that are closely related to the quality of life in urban areas. These benefits include air, temperature, air pollution, water conservation and increased biodiversity. Secondly, the social benefits of urban trees for the community were analysed, stressing the importance of trees for citizens' physical and psychological well-being. It has been shown that urban areas that are well provided with trees usually have lower levels of violence and crime. Thirdly, the review shows that urban trees can provide direct economic benefits such as increased property values. The review clearly demonstrates that urban trees not only contribute to the aesthetic quality of open urban spaces, but are strategic to improving the quality of life and sustainability of urban areas.

Key Words: Urban trees, Benefits, Silviculture, Urban Forestry.

1. INTRODUCTION

The city is the cultural landscape par excellence where great changes have taken place in terms of patterns of establishment in recent decades. Although, initially, cities were mainly integrated into their natural surroundings, thus equipping them with all the basic physical, social and natural services, they have evolved into large metropolitan areas with a multitude of functions (leaving a profound mark on the environment) (Curihuinca, 2001).

On the other hand, we find ourselves in a situation where the world's population is rising steadily. According to forecasts, by the year 2050 the world's population will number some 9,300 million people, 97% of whom will live in developing countries. Despite this enormous growth, the demographic increase in the world's population is unevenly distributed. Indeed, 80% of this increase in population has occurred in cities. In 1990, 540 million people lived in the 100 largest cities of the world. Today, only 3 out of the 10 most populated cities are located in developed regions (Tokyo, New York and Los Angeles), while the rest belong to the Third World or developing countries.

Since their origins, Latin American countries have enjoyed a close relationship with the environment that surrounds them. Cities in this part of the world were established in places offering many environmental advantages, thus placing them at an advantage over other First World countries. Let us not forget that the model of "Chinampas" of Xochimilco in Mexico City and tree-based agriculture was designed by the Aztecs and still prevails, or that the Chapultepec Forest in the same city was designed and maintained as a sanctuary-garden by the Aztecs. However, in recent decades, the increase in population and new economic patterns are leading to the creation of cold and uninviting urban landscapes, cornering citizens into small naturalised enclaves, most of which are far removed from their residential surroundings. This struggle for space forces citizens to define their priorities and needs when perceiving how they want their district to be, meaning that, in many cases, the presence of green acquires elitist connotations. There is no doubt nowadays that green spaces and urban trees have become another element of a city's image, providing extensive areas with environmental, social and economic benefits, as well as modifying the urban space in which they are planted.

Furthermore, society has become increasingly concerned with the importance of environmental values. Ecological relationships are now considered to be of vital importance and citizens are preoccupied about their current well-being, consumption and the poor exploitation of natural resources.

This review is a summary of the data acquired regarding interests, concerns and awareness about trees whilst Dr. Carlos Priego-González de Canales was conducting his doctoral studies in the PhD programme in Environmental Sciences in Chile. For a period of four years, the

author traveled to the main cities of the country where he discovered the enormous environmental problems troubling them. After numerous conversations with directors of the Parks and Gardens Departments on the shortage and poor state of urban trees, he concluded that there exists great ignorance concerning this important subject.

This review is the result of those experiences and a long and thorough search of various data bases and the study of scientific documents, press articles and international organizations devoted to the study and research of urban trees. During the writing of this review, access to scientific journals in both paper and electronic format on the subject of Urban Ecology in Latin American countries was very difficult. Books and written documents were purchased in Europe and North America, taking advantage of trips made by staff at the Eula-Chile Environmental Research Centre of the University of Conception, Chile. Contact was also made with authors of recent research studies, who generously sent some of their publications. Dr. Carlos Priego-González de Canales also attended urban scenery and landscape seminars throughout Chile.

The aim of this review was to produce a document that brings together the most important information and the most relevant bibliographies on the benefits of urban trees for society by incorporating studies and bibliography from the fields of urban planning, architecture, climatology, botany, environmental chemistry, medicine, economics, psychology and sociology. The review was made with the aim of increasing the awareness of policymakers, greenspace managers, natural resource planners and residents who are concerned about their environment.

2. ENVIRONMENTAL BENEFITS

2.1. The effects of urban trees on air quality.

2.1.1. Urban Microclimate.

Temperature is a sensitive meteorological variable in urbanisation processes. Higher temperatures are recorded in city centres than in natural surroundings. This urban effect on the superficial thermal field in the city is called a “heat island,” (López *et al*, 1991; Akbari *et al*, 1992; Moreno, 1994; Tso, 1996; Camilloni & Barros, 1997; Álvarez, 1998; Klysik & Fortuniak, 1999; Saaroni *et al,* 2000). Some of the main factors that cause this phenomenon include: constructed spaces that store and emit heat, the layer of atmospheric contamination, the low evapotranspiration rate in urban centres, products of tiny green areas and ground impermeability, heat given off by automobiles and industrial activity (Santibañez & Uribe, 1993).

Howard (1833) first referred to this phenomenon in his study "*The Climate of London*," when comparing the temperatures and humidity of the environs of the city of London, attributing this difference in temperature to the intensive uses of fuels.

Numerous studies on this subject have been published in North America and Europe, where the moderating effect of trees on temperature and humidity in urban areas has been demonstrated by comparing data from streets with and without trees (Heisler & Herrington, 1976).

Olmos (1991) and Peck & Callaghan (1999) affirm that vegetation directly influences city temperatures, cushioning the summer rigors and decreasing the intensity of heat islands. This fact is further justified, among other reasons, by an increase in surfaces which are protected from solar radiation by the shade of the trees. On the other hand, vegetation increases the environmental humidity thorough transpiration and field irrigation, with a consequent thermal relief (Bernatzky, 1969).

Leonard (1972) found that the transpiration of a mature tree corresponds to a refrigerator with a capacity of more than 150,000 thermal units/BTUs per day. A large mature tree is able to transpire 450 litres of water per day. This enables it to consume 1000 MJ of caloric energy in order to carry out the transpiration process, thus lowering urban temperatures (Hough, 1989). On the other hand, Montolío (1988) used luxometry and radiometry to determine and quantify measurements of the beneficial effects of a tree-lined road in the city of Valencia (Spain).

Studies conducted by the School of Agricultural and Livestock Sciences at the University of Entre Ríos (Argentina) and by Saito *et al.* (1991) have demonstrated that significant differences exist between the patterns studied in buildings surrounded by green zones, than those without them. In some cases, temperatures can be as much as 4°C hotter and there can be as much as an 11% difference in humidity in areas without green zones.

The importance of vegetation in the city depends on the urban areas themselves and on the type of vegetation and its configuration (Bernatzky, 1983; Wilmers, 1991; Svensson & Eliasson, 1997). Honjo & Takakura (1991) found that the benefits of vegetation in terms of climatic effects are greater in areas with a larger surface area of vegetation than in others with a smaller surface area.

2.1.2. Atmospheric pollutants

Trees reduce the gaseous agents that pollute the atmosphere by attracting them through the stomas of the leaves. Once within the leaves, they react with the internal structures (Smith, 1978; 1990). Doubtless, vegetation plays a key role in reducing small particles that are suspended in the atmosphere. Some particles can be absorbed by the trees (Ziegler, 1973; Rolfe, 1974; Givoni, 1991), although most of the particles that are intercepted are retained on

the surface of the plant. These particles located on the surface will return to the system when the leaves fall off or when they are washed off by the action of rain. In this way, trees constitute an effective way of temporarily retaining many atmospheric particles.

In 1994, the trees in New York City eliminated approximately 1,821 metric tonnes of atmospheric polluting agents, saving the city some $9.5 million. The improvement in the air quality of New York due to the removal of pollution by trees during the daytime during the in-leaf season averaged 0.47% for particulate matter, 0.45% for ozone, 0.43% for sulphur dioxide, 0.30% for nitrogen dioxide and 0.002 for carbon monoxide. The elimination of these polluting agents by the urban trees of New York City was greater than in Atlanta (1,196 tons; $6.5 million) and in Baltimore (499 tons; $2.7 million). However, the elimination of polluting agents per m^2 of covered surface was similar among the cities (New York: 13.7 grams/m^2/year; Baltimore: 12.2 grams/m^2/year; Atlanta: 10.6 grams/m^2/year). The percentage of polluting agents that are eliminated varies according to the amount of atmospheric pollution, duration of the leaves on the trees, precipitation, and other variables. Healthy trees that are larger than 77 cm in diameter eliminate approximately 70 times more annual atmospheric pollution (1.4 Kg/yr) than trees that are smaller than 8 cm in diameter (0.02 Kg/yr) (Nowak, 1994a; 1994b).

2.1.3. Carbon absorption: CO2 cycle

The rapid expansion of cities, a phenomenon that is associated with an increasingly industrialised world, has likely contributed to global warming and climatic change. There is no doubt that carbon dioxide is one of the gases responsible for the global warming effect, affecting atmospheric contamination. In 1990 the European Union, Russia and Japan contributed 50.2% of the CO_2 emissions to the planet's atmosphere. It is estimated that the urban trees in Syracuse store some 163,500 tons of carbon and have an annual carbon uptake of 3,870 tons/yr . As CO_2 is an important greenhouse gas that contributes to global warming, the value of the effect of urban forests on carbon is estimated at $3 million for storage and $71,500/yr for uptake. (Nowak *et al*, 2001)

Cities have always been the largest consumers of energy. The use of fossil fuels by vehicles has caused man to compromise the CO_2 cycle. Clearly, these problems can be significantly mitigated by planting large masses of vegetation inside the cities (Dwyer *et al*, 1992; McPherson *et al*, 1995; MacDonald, 1996). A study revealed that the urban forest of Milwaukee, Wisconsin, removes 1,521.3 tonnes of carbon per year. In Austin, Texas, trees cover around 30% of the city, removing 5,196.3 tonnes per year (MacDonald, 1996). In Chicago, urban forests remove 5.6 million tonnes of carbon annually, amounting to 1-2 % of all urban emissions (McPherson *et al*, 1995). During the summer of 1991, the urban forests of the counties of Cook and DuPage in the Chicago area eliminated, on average, 1.2 metric tonnes

per day of carbon monoxide, 3.7 t/day of sulphur dioxide, 4.2 t/d of nitrogen dioxide, 10.8 t/d of ozone and 8.9 t/d of suspended particles less than 10μm in diameter (Nowak, 1994).

2.1.4. Volatile Organic Compounds in the air

The emission of isoprenes and monoterpenes by certain arboreal species comprises a large fraction of the volatile organic compounds emitted in the atmosphere. Different studies have demonstrated the importance of arboreal VOC in the formation of photochemical oxidants such as ozone (Brasseur & Chatfield, 1991; Fehsenfeld *et al*, 1992). The Mediterranean Region constitutes the main source of tropospheric ozone in Europe; a fact that is probably due to the characteristic vegetation in the region (Seufert *et al*, 1995; Versino, 1997). Studies carried out by Staudt *et al* (1997) demonstrated that Pinus *pinea* was the largest source of this type of contamination in the Mediterranean Region. Other species of the genus *Eucalyptus*, *Quescus*, *Platanus*, *Populus*, *Rhamnus*, and *Salix*, generate a great amount of VOC (Benjamin *et al*, 1996; Benjamin & Winer, 1998). On the contrary, several species of the genus *Fraxinus*, *Ilex*, *Malus*, *Prunus*, *Pyrus*, and *Ulmus* generate little VOC. The use of these species in urban surroundings would improve the quality of the air.

The effects of interactions among trees on the physical and chemical environment demonstrate that trees can cause changes in pollution removal rates and meteorology, particularly air temperatures, wind fields and atmospheric stability which, in turn, affect ozone concentrations (Nowak *et al*, 2000).

This indicates that VOC emissions from trees can vary with the species, their location and other environmental factors such as temperature and solar radiation (Tingey *et al*, 1991; Guenther *et al*, 1994). Although vegetation reduces temperature - a determining factor in the formation of VOC - good vegetation cover in cities also reduces the formation of O_3 (Cardelino & Chameides, 1990; Dwyer *et al,* 1992).

On the contrary, isoprenes and monoterpenes are natural chemical substances from which essential oils, resins and other plant products are obtained and which serve to attract pollinators or repel predators (Kramer & Kozlowski, 1979).

2.1.5. Energy effects in construction

In recent years, numerous studies have demonstrated the effectiveness of urban forests in changing the temperature in the inner areas of cities, in some cases leading to a considerable reduction in the use of energy by different refrigeration and heating systems (McPherson, 1991; Dwyer *et a*l, 1992; Heisler *et al,* 1995; Laverne & Lewis, 1995; McPherson *et al*, 1995; Gangloff, 1996; MacDonald, 1996; Bolund & Huhammar, 1999; Peck & Callaghan, 1999; Simpson, 2002). Planting trees around houses reduces wind speed during the winter and the

intensity of solar radiation during the summer, thus leading to a reduction in costs derived from heating and air conditioning (Laverne & Lewis, 1995). A study developed in Sacramento, California, analysed the energy saved over 129 days by the shade of trees surrounding two houses. According to the results of this study, one of the households saved a total of 27% in energy costs, while the other saved 42% (Akbari *et al*, 1997). In a nursery in Miami it was demonstrated that planting shrubs and trees from 2 to 8 meters high around the building resulted in 50% savings in air conditioning on warm days and a total annual average savings of 25% (Parker, 1981; 1983). Heisler (1986) observed a reduction of about 10-15% in heating system costs thanks to the wind-breaking action of trees. On the other hand, shade and cooling through evapotranspiration led to a 20% to 50% reduction in refrigeration costs during the summer. The effect of tree shade on buildings was also analysed by Konopacki & Akbari (2000) in several American cities. The data were collected from different environments, namely stores and buildings. They demonstrated that by planting an average of 4 trees per house, $6.3 million were saved in the city of Baton Rouge, $12.8 million in the city of Sacramento and $1.5 million in Salt Lake City. The hard, crystallised surfaces of buildings reflect solar radiation, which is then returned to the atmosphere in the form of energy. Vegetation absorbs this energy by using 80% for its subsistence and for creating biomass, while only 20% of the solar energy is reflected off the vegetation and returned to the atmosphere. Thus we can say that the heat emitted from buildings, industries and vehicles increases air pollution levels in the city, which in turn increases temperatures by several degrees as compared to rural areas.

Nevertheless, trees planted in inappropriate places can actually increase energy costs (DeWalle, 1978). Studies demonstrate that trees that decrease the amount of wind can adversely affect the energy balance in three ways by: a) lowering heat dissipation from sun-heated surfaces, b) producing small drafts in buildings, mainly in old constructions, c) reducing the effectiveness of open windows during the summer, therefore leading to a more widespread use of air conditioners (Simpson, 2002).

The inclusion of trees in arid zones can also increase a city's maintenance costs. Nevertheless, in Tucson, Arizona, 16% of the annual irrigation required for trees was offset by the energy savings gained from the shade of trees (Dwyer *et al*, 1992).

2.2. Water conservation and reduced erosion

Water has always played a key role in human settlements. Streams, rivers and lakes provide food, defence and primarily drinking water to the population. With the growth of cities, catchment basins have undergone great transformations such as the canalisation of rivers, the drying up of humid areas and the overuse of cement and asphalt, thus creating an

impermeable crust for the action of the water in cities and therefore affecting the natural hydrology of these areas (Peck & Callaghan, 1999).

Water filtration rates into aquifers depend on the way land is used. In forest lands, 40-50% of the water is filtrated, while runoff accounts for 10-20%. In urban residential lands, 35% of the water is filtrated, while 30% is runoff. In urban lands, filtration rates drop to 15% with 55% runoff; water which subsequently slips through paved areas, drains and channels until reaching rivers (EPA, 2003). In Toronto, runoff from city waters transports pesticides, fats, heavy metals and rubbish and is the principal cause of water contamination in local rivers (Peck and Callaghan, 1999).

Urban trees in conjunction with naturalised areas function as absorbent water sponges, thus contributing to the absorption of nutrients and acting as a water supply source for aquifers. These spaces lessen runoff, diminishing the costs of their treatment (Sander, 1986). In Milwaukee, where urban trees cover 16% of the city, stormwater flow was reduced by 22%, leading to a savings of $15.4 million dollars, thus making it unnecessary to build additional systems to retain the water and mitigate this problem. In Austin, Texas, urban trees cover 30% of the city's surface area, thereby reducing rainwater flow by 28% and saving $122 million (MacDonald, 1996).

2.3. Noise pollution

Trees have been used for a long time as natural barriers to dissipate noise. Aylor (1972) showed that vegetation reduces sound by dissipating it, whereas the ground absorbs it. Different studies have been carried out on this subject. While Reethof (1973), Cook & Haverbek (1971), Herrington (1976) and Reethof & Heisler (1976) have focused on the qualitative aspects of trees, such as the type of species or the distribution of trees within the city to reduce noise, Embleton (1963), Aylor (1972) and Kragh (1979; 1981) have paid more attention to the quantitative aspects of trees, considering the density, height and thickness that these walls of vegetation must have. These studies have concluded that parameters regarding vegetal walls are the most effective factors for reducing noise in cities (Cook & Haverbek, 1971). On the other hand, resonant absorption depends on leaf size and the characteristics of the branches (Aylor, 1972). The foliage structure of the vegetation can disperse the acoustic concentration of waves in sites near the emission source (Cook & Haverbek, 1971), while dispersion diminishes with the distance from the source (Embleton, 1963).

Wide and dense vegetation belts up to 30m can reduce noise by about 50% (Cook, 1978). When the vegetation is dense and is put in front of a row of shrubs, noise is reduced by 3 to 5 decibels for walls with widths of 3m or less (Reethof & McDaniel, 1978). The human perception of sounds is another important factor to take into consideration. By blocking the visual origin of

the sound, vegetation reduces the perception that individuals have of the amount of noise they can actually hear (Miller, 1988).

2.4. Increased Biodiversity

The diversity of life on earth, which ranges from microorganisms to plants and animals, represents a wealth of resources whose values we are still learning to appreciate. Biodiversity contributes certain benefits to society such as food, medicine and building materials and to the ecosystem, including water purification, recycling of nutrients and carbon trapping. Trees also provide shelter for urban wildlife. Many types of insects feed on trees and in turn provide food for other insects and birds. Some birds and small mammals feed directly on tree pollen, flowers and fruits. Birds also use tree branches for courting displays and nesting

Urban areas, and in particular cities, significantly affect the ecosystems that originally existed in these places. The loss of forests and changes in river basins and land use has led to the disappearance of natural spaces and resources that once benefited man both physically and economically. However, numerous countries are taking steps to revert these processes in their cities. The creation of green spaces such as parks, gardens or squares for the conservation of biodiversity (Santandreu *et al*, 2000) is one example of the measures that have been taken in this regard.

Studies have found that many city inhabitants enjoy and appreciate the fauna in their daily lives (Shaw *et al*, 1985). It is therefore important to develop and create rich habitats that will increase urban biodiversity and serve to complement the many functions of urban forests (Johnson *et al,* 1990).

This demonstrates that the city can be perceived of as a new type of ecosystem with a different environment formed by species and peculiar habitats (Sukopp & Werner, 1983; Hostetler & Knowles, 2003).

A research study conducted over a period of 17 years by a family with a small garden of herbs, shrubs and trees found 140 different species, including 64 species of birds, 5 species of small lizards, 6 species of frogs and over 70 different species of insects. The creation of habitats for species that otherwise would not be there was the cause of great excitement and enjoyment for this particular family (Gardening Australia, 1999).

Other studies have demonstrated a high density, but few species of birds in cities. The variability of wealth and densities is directly related to the degree of urbanisation, urban woodlands and the variety of habitats in the city (Woolfenden & Rohwer, 1969; Emlen, 1974; Walcott, 1974; Degraaf & Wentworth, 1981; Blair 1996).

3. SOCIAL BENEFITS

3.1. Ecological awareness

The naturalisation of a city may provide the city's inhabitants with an important opportunity to learn about ecological principles and their interconnections with other aspects of life. The observation of urban nature and all its components (trees, shrubs, herbs, birds, insects, etc) has always been an opportunity for experimental learning. Studies by the Canadian Environmental Agency (1999) reported that in 1996, 43% of Canadians were involved in outdoor activities in natural areas, while 40% (9 million people) participated in wildlife-related activities in or near their residences. As Hough (1989) suggested, the discovery of nature at home during vacations is vital for developing environmental awareness. Recent evidence suggests that this raised awareness is directly relevant to processes of naturalisation in certain areas and serves to bridge the gap that separates people from the natural processes in these areas. Urban trees constitute a nexus between urban and rural life insofar as they naturalise our cities and our lives and raise citizens' ecological awareness. The leaves of trees fall, change their colour throughout the seasons of the year, are home to a diversity of species and undergo a multitude of alterations. Without them, the streets of our cities would be unchanging and monotonous. Community programmes to plant trees can help to lighten the burdens of living in the city, especially for low-income groups (Dwyer et al, 1992; Miles *et al,* 1998). In addition to benefits for plants and animals, restoration also offers numerous advantages that should be harnessed (Jordan, 1989; Hartig *et al*, 1994). A study conducted with several volunteers in Illinois who were working on restoration projects such as gardening, planting trees, pruning, sweeping leaves, etc, indicated that these different tasks led to a great sense of connection with nature and an enormous feeling of satisfaction (Miles *et al*, 1998).

3.2. Community Identity

For some time now, environmental planners have studied the form of residential architecture, building dispersion and the characteristics of public spaces; characteristics which could facilitate the formation of communities inside neighbourhoods (Altman, 1975; Brown & Werner, 1985). At the same time, social ties are considered to be strongly influenced by population density, lack of privacy and noise, all of which inhibit contact between neighbours and result in poor social relations in the community (McCarthy & Saegert, 1978; Tognoli, 1987; Keane, 1991; Kuo *et al,* 1998a).

The presence of vegetation in public spaces could form a barrier, thus providing visitors with a sense of security. Kuo *et al. (*1998b) studied people who experienced fear and felt uncomfortable in public spaces. The results of Kuo's study confirm that when vegetation is introduced in spaces that were previously devoid of vegetation, people changed their attitudes

and feelings. This fact demonstrates that vegetation can create common bonds between the inhabitants of a district. Another study demonstrated that the dwelling time in a park or public space depends on the presence, location and number of trees (Coley *et al,* 1997; DePooter 1997). In this way, trees and plants play an important role in attracting people from a district to its public spaces by embracing common interests and creating social bonds between residents. This opportunity for social contact has been demonstrated in the studies by Lewis (1996) and Berman (1997). They showed how neighbourhoods with plans to naturalise their districts, in which residents worked and organised together, began to develop a neighbourhood identity as they came to know each other better, develop a sense of unity and share a common belief in what they were doing.

Kuo et al, (1998a) found that in public spaces where there is more vegetation, the social ties between visitors are stronger in their own environs as compared to citizens who visited other people's green public spaces. Nevertheless, the use, enjoyment and creation of these spaces requires an involved and participating community (Hester, 1984). Active participation by neighbourhood communities in tree planting programmes has been designed to raise or increase the social identity of the community and to incorporate psychological benefits (Miles et al, 2000). It has been demonstrated that neighbours can work together on tasks related to the control of areas of the environment (Dwyer, 1995; Kuo *et al*, 1998a).

Kweon et al. (1998) reported that a great number of older people with strong social connections have lower levels of mortality, reduced rates of suicide, less fear of being the victims of crime and better physical and psychological health.

3.3. Influence on citizen safety

It should come as no surprise that crime and violence have always existed. However, the enormous migratory flows from rural to urban areas to seek work, new opportunities and better living standards, have turned cities into a breeding grounds for poverty and strife as a result of violence and crime.

Vegetation has always been an ‘accomplice’ to acts of vandalism, disturbing the relative safety of many large cities throughout the world. As a result, many cities have chosen to clear their streets and parks of trees and shrubs (Talbot & Kaplan, 1984; Nasar & Fisher, 1993; Michael *et al,* 1999; Weisel *et al*, 1994). However, Kuo & Sullivan (2001) suggest that vegetation with trees can inhibit crime in some districts in two ways: 1) by increasing surveillance and 2) by mitigating some of the precursory psychological factors of violence. Jacobs (1961) introduced the idea of “eyes in the street” in reference to the notion that increased surveillance would put a stop to criminal acts. This idea was later taken up by Jeffery (1971) in “*Prevention of crime through environmental design*”. Another concept based on this idea is that of the “Social

Control of the neighbourhood" and "Territorial Functioning", both of which refer to the fact that criminals tend to avoid areas which are frequented and taken care of by neighbours (MacDonald & Gifford, 1989; Brunson *et al* (at press), even when watchmen are not present (Newman, 1972). A study using photographs of residential houses examined the effect of architecture and landscape features with respect to the fear of crime. According to the results of this study, houses with trees and shrubs are safer than those without (Brower *et al*, 1983). However, another study based on computer simulated imagery studied spaces inside the city, rejecting the notion that cities with a larger density of trees provide a greater feeling of security (Kuo *et al*, 1998b).

Stame (1993), Kuo & Sullivan (2001) and Brunson *et al* (2001) have found that homes with more trees experienced less domestic violence than identical homes with fewer or no trees. The residents of houses with trees are normally more constructive and display less intra-family forms of violence and conflicts (Sullivan & Kuo, 1996). In addition, residents with more trees and lawn area on their properties state that they are "safer living there" than in areas without trees (Kuo *et al*, 1998b).

It is interesting to note that during the disturbances that occurred in Los Angeles following the Rodney King verdict (a black citizen who was stopped and subsequently mistreated by the police), the environs of the neighbourhoods were severely damaged, yet communities with gardens were less damaged (Brunson *et al,* (no published results).

3.4. Mental and physical health

The stress, hard work and pace of life characterizing our times has caused urban populations to become irritable, unsociable and lose their enthusiasm for accomplishing other deeds (Sorte, 1995). Researchers confirm that visual and physical contact with natural surroundings produce other physiological states that can be less stressful for humans (Kaplan, 1973; Ulrich, 1976; 1984; Jackson, 2001; Frumkin, 2001; Hill, 2002). A study carried out by Honeyman (1992) demonstrates that youth who saw scenes of natural landscapes, including those who observed scenes of urban vegetation, considerably lessened their levels of stress. When exposed to urban scenes, however, stress levels increased. Honeyman concludes that "the exclusion of vegetation in urban areas negatively affects human psychology, increasing the levels of stress" and that therefore, "the inclusion of vegetation in the city has positive impacts on population".

Furthermore, contact with nature affects work satisfaction and well-being (Kaplan, 1993), lessens mental fatigue (Kaplan & Kaplan, 1989; Sorte, 1995; Ulrich & Simon, 1986), changes moods and reduces pressure (Hull, 1992).

Besides contributing to the aesthetic quality of urban streets and communal parks, trees provide important emotional and spiritual experiences in the life of the population,

strengthening our roots to particular places (Schroeder, 1989; Chenoweth & Goster, 1990). Trees, shrubs and herbs have an intrinsic interest to men, they attract our attention and allow us to rest both physically and mentally (Schroeder & Lewis, 1991; Rohde & Kendle, 1994)

Another study was carried out on patients undergoing post-operative care in a Pennsylvania hospital. While 50% of the patients could see tall trees through the windows of their hospital rooms, another 50% looked out on a brick wall. The results of the study found that the patients who had views of the trees recovered earlier and had a better medical history than those with views onto a brick wall (Ulrich, 1984).

Doctors recommend that patients participate in community gardening and park restoration projects as these activities involve considerable physical exercise that lead to greater health benefits and lower heart disease rates in both middle-aged and elderly people (Caspersen *et al*, 1985). Moreover, shady streets and parks lower the risk of problems associated with ultraviolet radiation (Heisler & Herrington, 1976; Heisler *et al* 1995)

4. ECONOMIC BENEFITS

4.1. Property values

Urban trees contribute to the vitality and economic stability of districts by increasing property values and therefore those of the neighbourhood. Most people think that districts with trees are attractive places to live. This demand for naturalised places has increased the value of homes compared to those lacking vegetation (Kitchen & Hendon, 1967; Correll *et al,* 1978; Morales, 1980; Morales *et al*, 1983; Dwell *et al*, 1983; Anderson & Cordell, 1988; Dwyer *et al*, 1992). A survey on sales of single family homes in Atlanta, Georgia, indicated that properties landscaped with trees increased their sales value by 3.4 to 4.5% (Anderson & Cordell, 1988). Another study carried out in the city of Salo (located 110 kms to the northwest of Helsinki) showed that the price of terraced houses with a view onto forests increased by 4.9% (Tyrvainen, 1999; Tyrvainen & Miettinen, 2000). Builders consider that houses with trees sell, on average, 7% better than similar houses without trees (Seila & Anderson, 1982; 1984).

In a survey of 250 residents from Detroit regarding their impressions on the existence of trees in urban zones, 90% of the respondents thought that the presence of trees increased the value of their properties by more than 10%. In addition, they associated the presence of urban forests with high income people, high property values and high educational levels, resulting in greater affluence (Getz *et al,* 1982). Increases in property values due to trees have a direct effect on the economy of the community. Nevertheless, from the owner's perspective, tax increases due to the trees is an additional cost.

Quantifying the value of properties with urban forestry is not always an easy task. The results of a study comparing the Hedonic and Expert approaches reported the importance of choosing

the correct variables, the interaction among them and the difficulty of analysing several variables such as “income and view quality, nice neighbourhood as an attribute and social implications of neighbourhood environmental quality interactions” (Price, 2002). This research study concludes that the context is very important in quantifying view quality value.

4.2. Benefits for the community

Society can reap important benefits from trees that range from improved health and energy savings to water filtration and the elimination of contaminating agents. The most important of these and the hardest to evaluate include comfort and well-being. Furthermore, trees contribute to the economic vitality of a city, neighbourhood or home. McPherson (1991) studied a plantation of 500,000 new trees in Tucson over a 40-year period to calculate the benefits to the community. Irrigation, pruning and rubbish removal costs were compared against the ecological benefits gained from planting these trees, for example, more moderate temperatures, the filtration of dust and the retention of run-off. The effects on temperature were quantified in terms of energy savings gained by reducing the use of air conditioning, while dust filtration and run-off retention were quantified by comparing the cost of using alternative control mechanisms such as paving streets (dust control) and the construction of pools to retain rainwater. For the first 5 years the costs outweighed the benefits, but for the following 25 years the benefits exceeded the costs three times over.

Another research study carried out in two American cities (Modesto and Santa Monica) by McPherson & Simpson (2002) quantified the benefits and costs of urban trees to these cities. The researchers calculated the economic benefits gained from energy savings, atmospheric carbon dioxide reduction, air quality improvement, stormwater runoff reduction and aesthetics. Their balanced studies included analysing data on expenditure associated with urban trees such as planting, pruning, removals, landscaping, repairs, leaf clean-up, administrative costs, claims and legal problems. The results of the calculations showed that trees provided net annual benefits of $2.2 million in Modesto and $805,732 in Santa Monica, with a cost-benefit ratio of 1.85:1 in Modesto and 1.52:1 in Santa Monica. They concluded that although these kinds of studies require large amounts of data and intensive numerical modelling, they are useful for providing cities with information about the benefits and associated costs of urban trees.

5. CONCLUSION

Urban trees act as a nexus between artificial and natural things. On the whole, cities are becoming increasingly uninviting and cold and are in dire need of more naturalised surroundings where citizens can experience a wealth of positive physical and psychological

sensations, allowing them to communicate better with one another and strengthen their social ties.

This review has brought to light the fact that in some countries and regions urban trees are no longer mere aesthetic accessories, but key elements that make cities more sustainable and liveable.

Urban trees contribute environmental, social and economic benefits to society, thus improving citizens' quality of life. Cities with large areas of vegetation enjoy numerous environmental benefits such as a marked reduction in temperatures and increased atmospheric humidity; benefits which are particularly important in countries or regions where temperatures are very high in the summer season. In addition, when urban trees are selected appropriately, they can help to decrease certain atmospheric pollutants such as carbon, COV and airborne particle matter.

Trees also play an important role in water retention. Urban trees in conjunction with naturalised areas work as absorbent water sponges by supplying water to aquifers and decreasing runoff, thus lowering water treatment costs.

Numerous research studies on the social aspects of urban trees have shown that citizens who are in contact with trees contribute to raising ecological awareness among the population. Moreover, the presence of trees and plants in cities gives visitors a sense of security, reduces crime rates and creates strong social ties among users. These benefits are corroborated by city planners and different world wide organizations such as the World Health Organization, which considers urban green areas to be essential to citizens' development.

But trees do not only award environmental and social benefits. They also provide cities with important economic benefits thanks to their role in moderating temperatures, filtrating dust, retaining run-off and reducing atmospheric pollutants. All these benefits translate into enormous savings for city councils, while contributing to making cities more liveable and more comfortable to live in.

In the last decade, in which indicators of sustainable development are a reference, knowledge about the environmental, social and economic benefits of urban trees for society have provided useful data for urban planners. Urban trees are no longer considered a mere aesthetic component of the city, but have come to be a part of the urban ecosystem, carrying out their own functions. These new fields of knowledge have contributed to the development of an interdisciplinary approach which encompasses such sciences as botany, ecology and urban landscaping; sciences that, at the present time, are basic pillars for our understanding of the urban ecosystem where urban trees play an essential part.

Figure I. Research on Benefits of Urban Trees. Design and Photographs: Priego C & Nieto M.

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